EVANSVILLE REGIONAL TRAVEL MODEL DEVELOPMENT

Technical Memorandum:
Automated Air Quality Conformity Analysis

Prepared for the

EVANSVILLE URBAN TRANSPORTATION STUDY

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Introduction

The Clean Air Act (CAAA) and the Transportation Equity Act for the 21st Century (TEA-21) require evaluation of transportation plans for areas that are designated as "non-attainment" or "maintenance" areas for the National Ambient Air Quality Standards (NAAQS) to ensure consistency with air quality planning efforts. Certain activities require that a conformity determination be made, namely the development of new or amended long-range transportation plans or short-range transportation improvement programs (TIP) for Urbanized Areas.

To assist in required air quality conformity analyses, the Evansville Urban Transportation Study (EUTS) contracted with Bernardin-Lochmueller & Associates (BLA) to develop a micro-computer program to interface with and post-process the output of the new Evansville Regional Travel Model, also developed by BLA for EUTS.
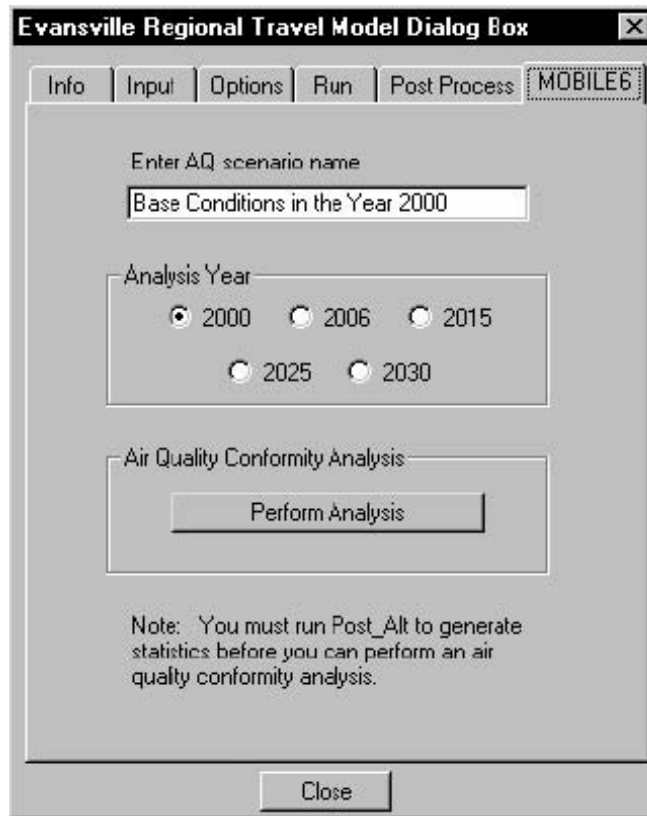
Figure 1: Air Quality Post-Processor User Interface

The air quality post-processor program was written in the GIS/DK programming language and incorporated into the travel model's user interface in the TransCAD software environment. This enables the user to run the air quality program after making a travel model run by the simple push of a button. The user needs only to specify the year of the analysis, and the program incorporates the parameters specific to the analysis area in that year. The user interface is displayed in Figure 1. The current program is designed only to determine conformity for Vanderburgh County, since it is currently the only non-attainment area in the Evansville region.[1] If due to new standards (e.g., the 8-hr ozone standard, etc.) or for other reasons future conformity analyses require the examination of other counties within the model area, the program could be modified in a fairly simple, straightforward manner to report emissions and conformity for other counties or the model area as a whole.

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[1] The emissions computations now include Warrick County.
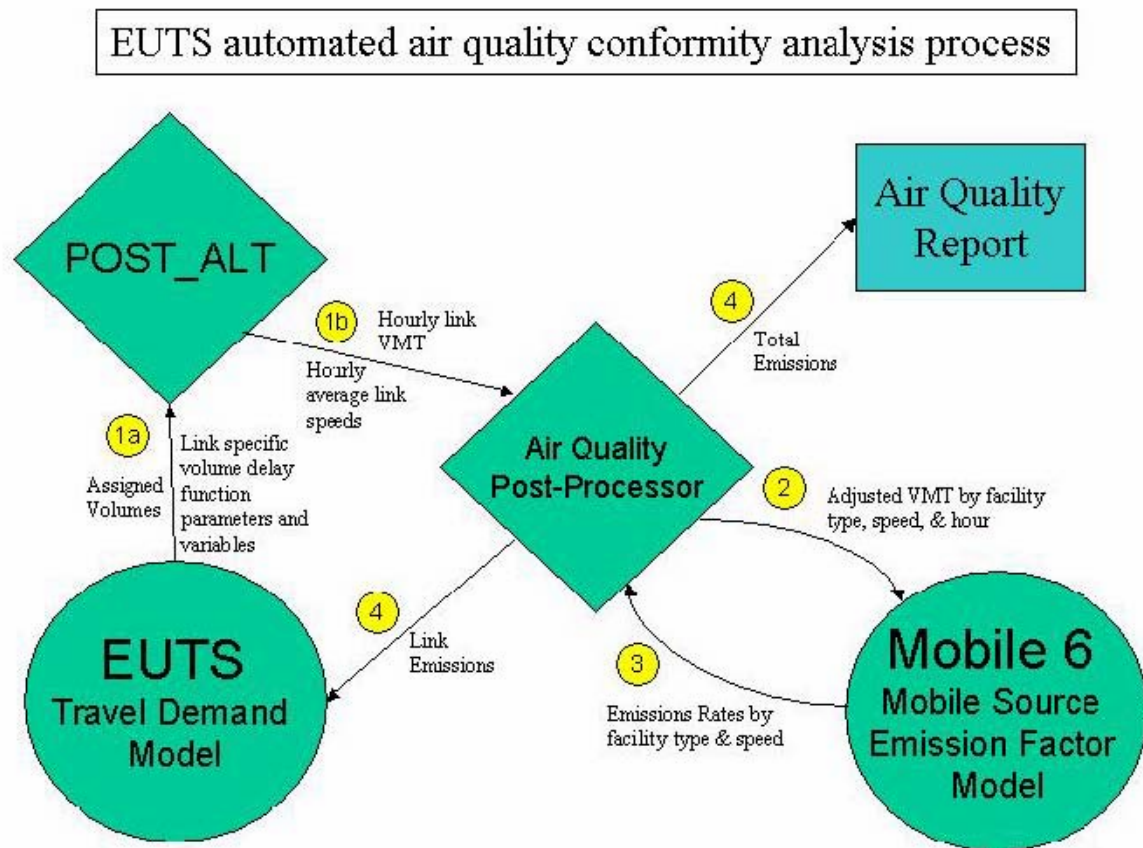
Figure 2: EUTS Automated Air Quality Conformity Analysis Process

The process of air quality conformity analysis automated by the post-processor is displayed in Figure 2. The process can be understood as being made up of four steps. The first step is the estimation of hourly link speeds and volumes. This step is accomplished by the POST_ALT post-processor for the travel model that also produces other traffic statistics. In the second step, the air quality post-processor (proper) adjusts and aggregates the link VMT from POST_ALT by facility type, speed, and hour of the day and passes this data along with the other standard inputs to the Mobile 6 model. The third step would be the series of thirty Mobile 6 runs to produce emissions rates by facility type and speed bin. The fourth and final step then consists of application of the rates from the Mobile 6 runs to the VMT to calculate the emissions and the reporting of these emissions on the network links and in summary in the report file.

Estimation of Hourly Speeds and Volumes

The average congested speeds for links in the model's roadway network used by the air quality post-processor are computed first by a post-processor for the travel model,

POST_ALT. POST_ALT, developed by BLA, passes to the air quality post-processor the hourly VMT and average speeds on each link in the model's roadway network. The air quality post-processor then tabulates the VMT on each facility type, in each speed bin, for each hour of the day. Harmonic means are used in disaggregating each link's hourly VMT into the upper and lower bins around its hourly average speed, as described in section 5.3.4 of the Mobile 6 User's Guide.

The hourly average speed for each link is calculated by using the traditional Bureau of Public Roads (BPR) volume delay function. Link specific parameters are used to adjust the link's free-flow speed on the basis of its hourly volume to capacity ratio to account for congestion related delay. The alpha and beta parameters for the BPR equation which are used in both the travel model's assignment procedure as well as the postprocessing are coded on the network links. Two sets of parameters were used in the EUTS model. Rural principal arterials and interstates were coded with an alpha of 0.83 and beta of 2.10. All other links were coded with an alpha of 0.84 and a beta of 5.50. These parameters are taken from *Delay-Volume Relations for Travel Forecasting, Based on the 1985 Highway Capacity Manual* by Alan Horowitz, published by the FHWA in 1991 and cited by the Travel Model Improvement Program's (TMIP) 1997 report on *Travel Model Speed Estimation and Post Processing Methods for Air Quality Analysis.* The link free-flow speeds were assigned on the basis of posted speed, functional class, number of lanes, and presence/absence of median; and on some facilities these free-flow speeds may have been subsequently adjusted in the calibration process. The speed table used in assigning speeds was developed on the basis of an extensive speed study conducted at over 60 stations in southwest Indiana for the study of I-69. The capacities used in the estimation of average speeds are absolute (LOS E) capacities from the Highway Capacity Manual. The last input to the volume delay function, the volume, is estimated by apportioning the model's assigned daily volumes using an hourly distribution and peak-period directional factor that are specified by the user. The examples given in this documentation all reflect the use of the a 60/40 directional split in the peak periods and an hourly distribution obtained by averaging the trip distributions reported in the 2000 Evansville Household Travel Survey and the 1995 Indiana Statewide Household Travel Survey.

A formal calibration/validation of speeds was not part of the BLA's services contracted to EUTS, nor was there average speed data available for the area necessary for such a process. Therefore, the validation of the average speeds was limited to reasonableness checks. However, POST_ALT has recently been calibrated for another urban model, using local peak period speed studies, and obtained a 36.1% RMSE with AM period speeds and a 31.5% RMSE with PM period speeds. This calibration was accomplished by dampening the hourly distribution from a household travel survey to account for a more disperse commercial traffic distribution and disproportionate underreporting of off-peak period trips. Averaging the distributions from the Evansville and Indiana statewide household travel surveys produced a fairly similar distribution due to the less peaked character of the statewide distribution. Another hourly distribution of traffic for the Evansville region was produced by dampening the distribution from the 2000 Evansville Household Travel Survey similarly as was done to achieve the calibration in the other

model. It could be appropriate to use either of these distributions (the average or the dampened distribution), but statistical agreement of the calculated speeds with observed speeds is not expected to be as good here because no observed speed data was available for calibration purposes.

Preprocessing for Mobile 6

The preprocessor for the thirty Mobile 6 runs produces a control file to implement the Mobile 6 runs and creates fifty-one external data files. The creation of the control file is very straightforward since most of the assumptions for the Mobile 6 runs can be hard-coded because they depend only on the air quality analysis area and do not vary from analysis to analysis. (These assumptions are recorded in the next section dealing with the Mobile 6 runs.) A representative Mobile 6 input control file created in the preprocessor is reproduced in Appendix A.[2]

The external data files created in the preprocessor are distributions of VMT in the analysis area by facility type, speed bin, and hour of the day. Examples of these external data files produced in the preprocessor can be found in Appendix B[3]. The preprocessor essentially cross tabulates the hourly link VMT's for each combination of facility type, speed bin, and hour of the day and then converts these sums into distributions. The Mobile 6 facility type is coded directly on the model's roadway network links in the field M6FT. Freeways are coded as 1, arterials (including collectors) by 2, locals by 3, and any ramps by 4 in the M6FT field. However, before the VMT can be tabulated, it must be adjusted to ensure relative agreement with HPMS and account for the underrepresentation of local streets in the model. [4]

Year 2000	Model		Model Adjusted		HPMS	
VMT	VMT	Share	VMT	Share	VMT	Share
Freeways	508,579	12.3%	508,579	11.6%	432,400	9.9%
Arterials	3,365,478	81.5%	3,365,478	76.6%	3,443,000	78.4%
Locals	213,065	5.2%	473,538	10.8%	476,000	10.8%
Ramps	44,224	1.1%	44,224	1.0%	37,600	0.9%
Total	4,131,347	100.0%	4,391,819	100.0%	4,389,000	100.0%

Table 1: HPMS vs. Model VMT Table

For each facility type, as well as for Vanderburgh County as a whole, the daily VMT

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[2] This will be found in Appendix D of the SIP.
[3] This will be found in Appendix D of the SIP.
[4] The following table does not include Warrick County VMT. The program applied the same adjustment factor of 2.2225 to the Warrick and Vanderburgh "local" VMT to account for the underrepresentation of local streets.

reported by the travel model for the year 2000 was compared with the daily VMT estimates from the Federal Highway Administration's (FHWA) Highway Performance Monitoring System (HPMS). Because the travel model's roadway network does not contain ramps, the Mobile 6 national default was used to break out the model's total freeway VMT into mainline and ramp VMT. Because the model network also includes only a fraction of the local streets, it was expected that the VMT for local facilities would have to be factored up to yield an accurate estimate of VMT. The comparison revealed that if the VMT reported by the model for local roads was factored up to agree with the HPMS estimate, the total VMT and shares for each facility type were in good agreement between the model and the HPMS estimates. The base year VMT by facility type for Vanderburgh County are displayed in Table 1. The same factor was applied to the local facilities' VMT for future years as was used in the base year of 2000.

Automated Mobile 6 Runs

The air quality post-processor makes thirty Mobile 6 runs for each travel model run in order to produce a table of emissions rates by facility type and speed bin. An example of an emissions rate table produced by the post-processor is displayed in Table 2. Mobile 6 model documentation (User's Guide section *2.8.8.2.d*) makes clear that it is not inappropriate to use Mobile 6 to model emissions rates for roadway links separately. Section 4.5.3 of the TMIP's report entitled Travel Model Speed Estimation and Post Processing Methods for Air Quality Analysis also encourages the estimation of link based emissions and emissions rates.

Facility Type		Average Speed (in miles per hour)													
		2.5	5	10	15	20	25	30	35	40	45	50	55	60	65+
Freeway	VOC	12.96	5.46	3.10	2.43	2.11	1.96	1.85	1.76	1.71	1.66	1.58	1.61	1.63	1.59
	CO	58.29	34.50	21.84	18.17	17.10	16.52	16.16	16.19	16.82	17.49	17.12	19.74	22.25	22.81
	NOX	4.37	3.96	3.20	2.79	2.70	2.64	2.62	2.61	2.65	2.72	2.83	3.00	3.23	3.53
Arterial	VOC	12.96	5.11	3.04	2.44	2.11	2.04	1.95	1.84	1.77	1.72	1.68	1.65	1.62	1.59
	CO	56.29	33.14	22.12	18.78	17.13	17.68	17.67	17.71	18.37	19.14	19.99	20.97	21.82	22.65
	NOX	4.04	3.52	3.00	2.66	2.47	2.40	2.34	2.31	2.34	2.41	2.52	2.67	2.89	3.19
Local	VOC				2.86										
	CO				17.84										
	NOX				2.33										
Ramp	VOC								2.07						
	CO								27.90						
	NOX								2.30						

Table 2: Emissions Rate Table

Each of the thirty Mobile 6 runs assumes the same fuel volatility, VMT fractions for the various vehicle types, meteorological data, and vehicle fleet age mix. The fuel volatility

is assumed to be a Reid vapor pressure of 9.0 psi. The VMT fractions for the various vehicle types were borrowed from the previous air quality analysis done in 2000 in which data was obtained from the Indiana Bureau of Motor Vehicles (BMV).[5]   The meteorological data, including average daily low and high temperatures (68 and 89 degrees Fahrenheit), sunrise and sunset hours (7AM and 9PM), and cloud cover (27%), was taken from the *Comparative Climatic Data Publication* by the National Climatic Data Center (NCDC) specifically for Evansville, Indiana, in the month of July. The national vehicle fleet age mix was used for heavy truck categories, but for passenger cars and light trucks the age distribution of household vehicles from the 2000 Evansville Household Travel Survey was used.

The thirty Mobile 6 runs differ in the VMT for which they estimate emissions rates. Each run calls a different set of the external data files created in the preprocessor. Fourteen runs are made for freeways at various speeds, fourteen runs are made for arterials at various speeds, and one run each is made for local facilities and ramps. An example of the resulting Mobile 6 outputs are included in Appendix C[6].

Postprocessing of Mobile 6 Runs

The product of the Mobile 6 runs is a set of emissions rates. However, in order to determine conformity, these rates must be applied to the VMT to calculate the actual emissions. The post-processing of the Mobile 6 runs consists of this application of the Mobile 6 emissions rates and the generation of the report file.

Emissions are calculated differently for freeways and arterials than for local facilities and ramps. For freeways and arterials, emissions are computed for each link in the travel model's roadway network. Average link speeds by hour of the day (from POST_ALT) are used to distribute the hourly VMT on the link between the Mobile 6 speed bins using harmonic means as prescribed by Mobile 6 documentation. The emissions rates by facility type and speed bin are then applied to determine the emissions resulting from traffic on the link in each hour. The hourly emissions on each link are summed to produce the total emissions for the link and the emissions from each link are summed to produce total emissions for freeways and for arterials. The total daily emissions for each link are written to the link in the TransCAD network file in the fields: VOC, CO1, and NOX.

Since all local facilities and ramps are not included in the model's roadway network, their emissions cannot be calculated on a link-by-link basis. Moreover, Mobile 6 assumes specific speeds for these facility types based on national averages such that there would be little advantage to a link specific calculation in their case anyway. Therefore,

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[5] The VMT Fraction command discussed in the paragraph, which was developed using BMV data, was not modified for this budget run. However, new BMV data regarding vehicle fleet age for each county was acquired and used in the Registration Distribution command.

[6] This will be found in Appendix D of the SIP.

emissions are computed for all local roads and all ramps with one calculation for each category in which the total VMT for the facility type (computed in the preprocessor) is multiplied by the emissions rates for the facility type.

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Air Quality Conformity Analysis Report for Vanderburgh County
from MOBILE6 and the Evansville Regional Travel Model
Wed Oct 01 17:48:27 2003


Year: 2000
Scenario: Base Conditions in the Year 2000
         4391345 VMT in Vanderburgh County

              VOC                 CO                 NOX
Scenario:    9.01 tons/day     95.22 tons/day    12.44 tons/day
Budget:     16.29 tons/day    106.96 tons/day    12.52 tons/day
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Figure 3: Air Quality Post-Processor Report [7]

The total emissions for freeways and arterials are then added to the totals for local facilities and ramps to produce the grand total emissions for the analysis area. The program generates a report file in ASCII text format that reports the daily vehicle miles of travel (VMT) and daily emissions of volatile organic compounds (VOC), carbon monoxide (CO) and nitrogen oxides (NOX) for Vanderburgh County. The State Implementation Plan (SIP) budgets for the emissions of VOC, CO, and NOX are also included in the report to facilitate the determination of conformity. An example report can be seen above in Figure 3.

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[7] These are results of the base-year (year 2000) emissions estimates, and are not applicable to this budget analysis.